THE REORIENTATION EFFECT IN ^{114}Cd

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Cross section measurements for scattering of ^{4}He and ^{16}O ions from ^{114}Cd were found consistent with a zero static quadrupole moment of the 0.558 MeV 2^+ state.

Several experiments to measure the quadrupole moment of the first excited state of ^{114}Cd have been performed in the last few years [1-3] utilizing the reorientation effect of Coulomb excitation. For most practical purposes, the theoretical expression for the Coulomb excitation probability can be written [4] as $P = P^{1st}(1 + \alpha Q + \ldots)$. Here P^{1st} is the first-order expression for the excitation probability, proportional to the $B(E2, I_i \rightarrow I_f)$. The function α depends on the experimental conditions and Q is the static quadrupole moment. The usual way of determining Q is by comparing P for projectiles of sufficiently different mass or by measuring the angular dependence of the excitation cross section for a heavy projectile.

The sensitivity of the measurement to the value of the quadrupole moment is rather low. For ^{16}O on ^{114}Cd αQ is about 10% assuming a quadrupole moment of 0.8b. Therefore reorientation measurements require very high experimental accuracy, and in the past several techniques have been used in order to achieve the required precision. The experimental techniques fall into two categories: (a) particle - γ coincidence measurements and (b) direct inelastic cross-section measurements using particle spectroscopy.

In the first method, the ratio of excitation probabilities for two different projectiles is measured. The B(E2) value can thus be eliminated and the quadrupole moment deduced from the experiment.

In the particle spectroscopy measurements, the absolute value of the excitation probability is determined. As can be seen from eq. (1), the B(E2) plays an important role and must be determined to a very high precision, because of the low sensitivity of expression (1) to Q.

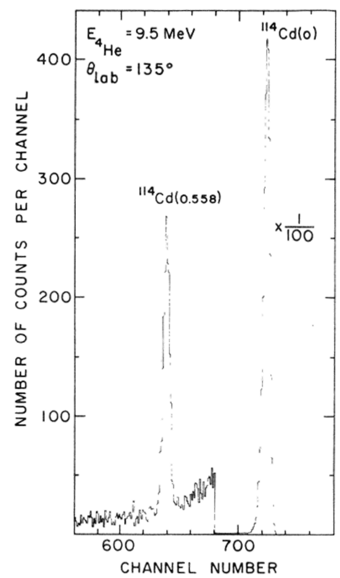

Fig. 1. Spectrum of 9.5 MeV ^{4}He ions scattered from ^{114}Cd at θ_{lab} = 135°.

The two experiments performed to date using the particle-spectroscopy method [2,3] give rather similar values for the quadrupole moment of ^{114}Cd, but their B(E2) values differ by about 10%. The effect of the quadrupole moment on the probability is also of the order of 10% and the discrepancy between the two experiments is disturbing. It was therefore decided to measure the reorientation effect in ^{114}Cd by comparing the excitation probabilities obtained by bombarding ^{114}Cd with ^{4}He and ^{16}O ions at different energies

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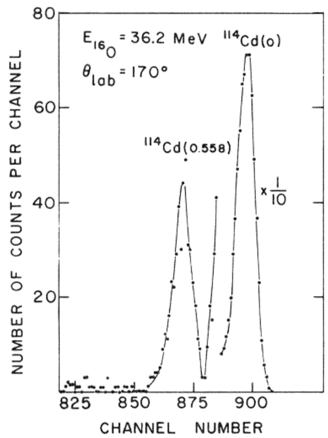

Fig. 2. Spectrum of 36.2 MeV ^{16}O ions scattered from ^{114}Cd at θ_{lab} = 170°.

and scattering angles. The technique has already been applied for ^{70}Ge and ^{76}Ge [5].

Well-collimated beams were used to bombard thin ^{114}Cd targets prepared from the enriched (99.09%) isotope and deposited on thin (20 $\mu g/cm^2$) carbon foils. The target thickness was 15 $\mu g/cm^2$ for the ^{16}O experiment and 80 $\mu g/cm^2$ for the ^{4}He experiment. The scattered particles were detected in solid state surface barrier counters which resolved the elastic and inelastic groups. Examples of the spectra are shown in figs. 1 and 2. Detecting the scattered particles in solid state counters has the advantage that no knowledge of the charge distribution of the scattered beam is necessary, in contrast with magnetic spectrometer measurements. The deduction of the excitation probability from the raw experimental data is quite straightforward.

Table 1.

Experimental values of $R_{exp} = d\sigma_{inelastic}/d\sigma_{elastic}$ for the 2^+ state in ^{114}Cd at 0.558 MeV, measured with ^{4}He and ^{16}O ions at different energies.

Projectile (lab angle)	E (MeV)	$R_{exp} \times 1000$
^{4}He (135°)	8.5	3.25 ± 0.06
	9.0	4.07 ± 0.07
	9.5	5.71 ± 0.13
	9.75	6.51 ± 0.20
	10.0	7.23 ± 0.17
^{16}O (170°)	36.2	57.7 ± 2.6

One disadvantage of this method is that elastically scattered ions from contaminants in the target might coincide in energy with the inelastic group and thus obscure the results. In the present work, the most disturbing contaminants for the ^{16}O experiment were the lighter isotopes of cadmium. Their abundances were taken from the suppliers assay. In the ^{4}He experiment a wide range of energies was used and no elastic peak from any contaminant could be detected in the experiments.

The experimental data are compiled in table 1. The data were analyzed with a multiple Coulomb excitation code similar to the one written by de Boer and Winther [6]. The nuclear levels and the quadrupole operator matrix elements between

Table 2.

Resulting values for $B(E2,\ 0^+ \rightarrow 2^+)$ and the static quadrupole moment Q_{2^+}. The analysis has been done for either choice of the relative sign of the matrix elements given in the table. The errors include an estimate of the uncertainties in subtracting the background in the spectra.

	Sign of $\langle I_i \| M(E2) \| I_f \rangle / \langle 0 \| M(E2) \| 2 \rangle$ +	−
$B(E2, 0^+ \rightarrow 2^+)$ $(e^2 \cdot b^2)$	0.508 ± 0.09	0.509 ± 0.08
Q_{2^+} $(e \cdot b)$	0.05 ± 0.27	0.21 ± 0.28

them were taken from ref. [2], leaving the matrices $\langle 0 \| M(E2) \| 2 \rangle$ and $\langle 2 \| M(E2) \| 2 \rangle$ as free parameters. The signs of the matrix elements $\langle I_i \| M(E2) \| I_f \rangle$ relative to the sign of $\langle 0 \| M(E2) \| 2 \rangle$ are not known. This introduces a certain ambiguity into the results, and the data were analyzed twice, for either choice of the relative sign of the matrix element connecting the first and second 2^+ states.

The results are compiled in table 2. It can be seen that the $B(E2)$ value of 0.51 $e^2 \cdot b^2$ is in very good agreement with the one obtained by Stockstad et al. [2] and in disagreement with the value of ref. 3. The quadrupole moment which is deduced from the data is rather small, and is certainly consistent with the value zero, for either choice of the relative sign of the matrix elements.

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